Contributions Toward an Integrative, Process-Based Model of Stratigraphy Formation

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LONG-TERM GOALS

My long-term goals are to improve our understanding of the physical evolution of the continental shelf and slope strata, and to enhance our ability to extract stratigraphic information from geophysical data of these regions.

OBJECTIVES

The specific objectives of this project are to:

- Aid development of the integrative stratigraphic modeling system SEQUENCE (Steckler, 1999) by:

  (i) helping create a component model for the long-term evolution of shelf strata, and

  (ii) creating a component model for the long-term evolution of slope strata.

- Develop a model for generating synthetic seismograms of stratigraphic simulations produced by SEQUENCE and by SEDFLUX (Syvitski et al., 1999), the second integrative stratigraphic modeling system being developed for ONR.

- Continue work on modeling of unconfined submarine debris flows and validate this work against experimental flows.

APPROACH

SEQUENCE is being designed to rapidly simulate the first-order evolution of continental margin morphology over long (geologic) time periods. To meet this requirement, the shelf and slope component models for SEQUENCE are 1-D, Eulerian, finite-difference models that produce 2-D, dip-line simulations of shelf and slope evolution. Both are relatively fast and encompass the physiographic provinces in their entirety, using annual to multi-year time steps, and distance steps of tens of meters. The shelf model simulates the formation of shelf strata under the combined effects of sediment supply, waves, and a long-term, net-offshore current. The slope model simulates episodic failure and/or the bypassing of sediments to the deep sea.

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14. ABSTRACT
My long-term goals are to improve our understanding of the physical evolution of the continental shelf and slope strata, and to enhance our ability to extract stratigraphic information from geophysical data of these regions.

15. SUBJECT TERMS

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The modeling of synthetic seismograms from strata generated by SEQUENCE and SEDFLUX requires two separate models. The first model generates the physical properties needed to produce synthetic seismograms, principally bulk and shear moduli. The second model uses these properties to simulate the theoretical response of the computer-generated strata to seismic energy, including its attenuation.

Submarine debris flows and the deposits they produce are being modeled in three dimensions using a 2-D, layer-averaged, numerical model of a Bingham fluid. The model is to be validated against unconfined experimental debris flows, the heights and velocities of which have been well documented.

The shelf and slope modeling is being done in collaboration with Drs. Pat Wiberg (UVA), John Swenson (UMinn-Duluth), Chris Paola and Gary Parker (UMinn-Minneapolis). The seismic modeling is being done with Dr. Anastasia Stroujkova (Duke/UConn). And the debris flow modeling is being done with Drs. Jim Buttles (MIT) and Gary Parker (UMinn-Minneapolis).

WORK COMPLETED

The main goals of this effort were largely completed in FY01. These accomplishments include:

- Development of component models for SEQUENCE that simulate the long-term evolution of shelf and slope strata.

- Linkage of these models with other component models that simulate the long-term evolution of the coastal plain and the continental rise.

- Development and validation of the model for simulating acoustic properties from computer- and laboratory-generated strata, which in turn can be used to simulate seismic reflection data.

- Development of a 1-D poro-elastic model of seismic wave propagation for producing synthetic seismograms of computer- and laboratory-generated strata.

- Completion of a series of laboratory experiments on the dynamics of unconfined debris flows and the deposits that they produce.

Work during FY02 has focused on exercising the above models, making them available to other ONR MGG PIs, and writing up results. The latter includes results on ancillary research undertaken as part of this grant, specifically an analysis of the potential impact of internal waves on the slope of the continental slope, which was done with Dr. Dave Cacchione (CME). The main accomplishments this year are:

- Preparation and submission to *Geophysics* of a manuscript on the acoustic property modeling (Stroujkova et al., in review)

- Completion of the internal-wave/continental-slope analysis, including publication of the results in *Science* (Caccione et al., 2002).

- Completion of algorithms for using SEDFLUX simulations in the acoustic-property and seismic-reflection models.

- Successful installation of the acoustic-property and seismic-reflection models at INSTAAR for use in future SEDFLUX simulations.

- Successful application of the acoustic-property model to SEDFLUX simulations of the New Jersey STRATAFORM/GEOCLUTTER study area.

- Continued development and testing of a numerical model for simulating unconfined debris flows.

RESULTS

- The *Geophysics* manuscript demonstrates that the acoustic-property model produces realistic results relative to the acoustic properties of natural strata and so is well suited for use in simulating how computer- and laboratory-predictions of strata would appear in seismic reflection data.

- The *Science* manuscript demonstrates that in the STRATAFORM study areas (and perhaps worldwide) sediment accumulation on the continental slope and thus its gradient may in part be controlled by bottom shear stresses produced by the internal tide (Figure 1).

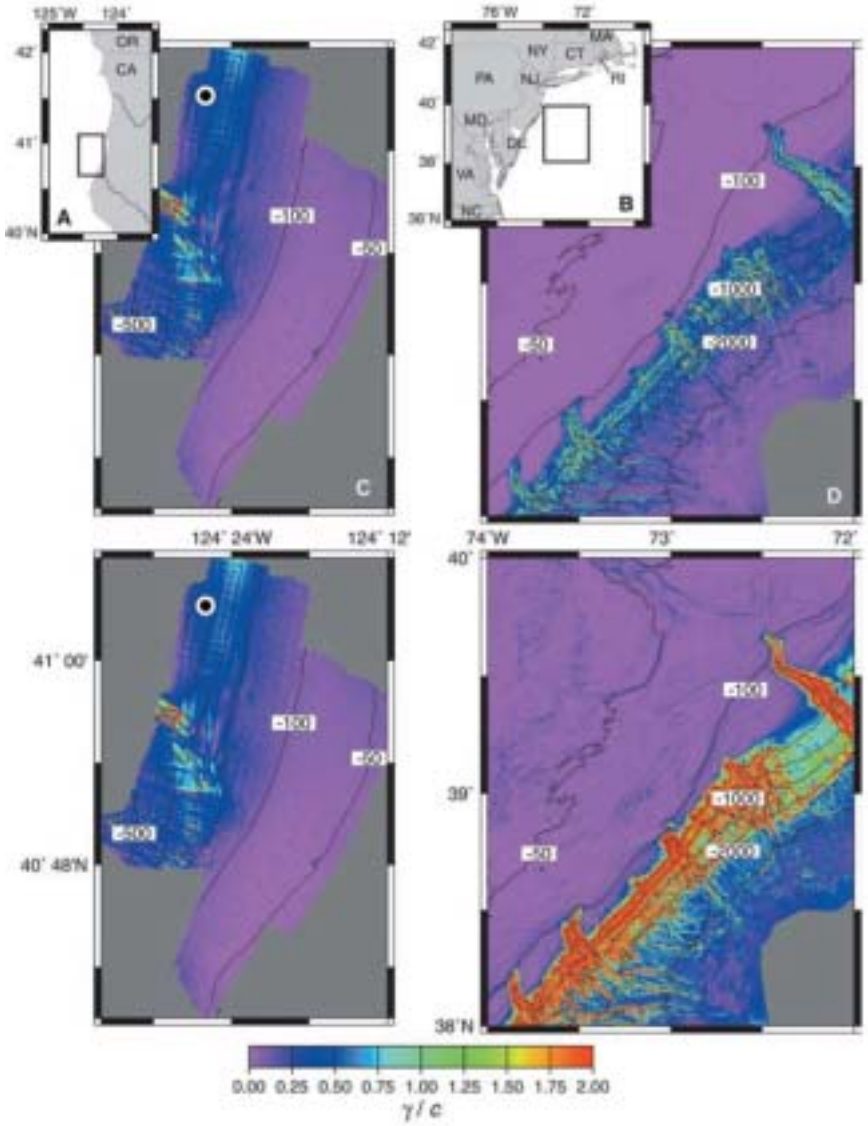

Figure 1. Ratio between seafloor gradient (γ) and critical angle for the internal tide (c) in the STRATAFORM California (left) and New Jersey (right) study areas during summer (top) and winter (bottom). Bottom shear stresses are predicted to be greatest where ratio is near unity, which is on the continental slope.

- The acoustic-property and seismic-reflection models are now up and running at INSTAAR, which will speed their application in simulating seismic reflection data of future SEDFLUX runs.

- The P-wave velocities and attenuations computed from the SEDFLUX simulation of the New Jersey STRATAFORM shelf area qualitatively similar to measurements of these properties made as part of the GEOCLUTTER program.

- The 2D debris flow has been validated against experimental results of confined debris flows. It has also been used to simulate unconfined debris flows, but for these types of flows the model becomes unstable after seconds of simulation time. Work on stabilizing the model continues.

IMPACT/APPLICATIONS

- The shelf and slope component models, as well as the coastal plain and basin floor component models have been integrated into SEQUENCE.

- The acoustic-property and seismic-reflection model can use SEDFLUX stratigraphic simulations as input and are now up and running at INSTAAR for future use as part of SEDFLUX.

- The internal-tide/continental-slope analysis has demonstrated the potential importance of internal waves in shelf and slope sedimentation and has already initiated a number of other such studies.

TRANSITIONS

- The shelf and slope component models have furthered the development of SEQUENCE.

- The acoustic-property and seismic-reflection models have furthered the development of SEDFLUX and will be used as part of SEDFLUX modeling in other ONR programs (e.g., Uncertainty DRI and GEOCLUTTER).

RELATED PROJECTS

- The acoustic-property and seismic-reflection models are being used in the ONR Uncertainty DRI.

- These same models will also now be further exercised and tested in the ONR EuroSTRATAFORM program.

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